Card Geotechnics Limited
Providing Ground Solutions

Urbanest UK Limited

103 Camley Street, London

Stage 2 Geotechnical and Geoenvironmental report

June, 2012

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EXECUTIVE SUMMARY

Urbanest UK Limited has commissioned Card Geotechnics Limited to undertake a *Stage 2 Geotechnical and geoenvironmental investigation* at 103, Camley Street, London. These works have been undertaken in relation to proposed redevelopment of the site to include multi-storey student accommodation, with a lower ground floor level intended for student business enterprises.

The site is located within a predominantly industrial/commercial area near to Saint Pancras International Station in the London Borough of Camden. The site is bounded to the east by Camley Street and to the west by the Regents Canal. To the southeast of the site there is an electrical substation and to the north there is residential development. The site was historically part of the Midland Railway Infrastructure but is now principally occupied by two warehouses and a number of portacabins and container units. The remainder of the site is utilised as a base for taxis. Five Underground Storage Tanks (USTs) are also present on site. The site lies at a higher level that the Regents Canal, and is supported on the western boundary by a wall retaining the site level.

Geological records show that he site is underlain by the London Clay Formation, which is classified as non productive strata in accordance with the Water Framework Directive (WFD). Therefore, the site does not lie within a Source Protection Zone. The site is not in a particularly sensitive environmental setting.

A previous investigation of the site was completed in 2000 by Albury SI Limited, which indicated the presence of some 5-6m of Made Ground on the site, comprising notable concentrations of lead and Total Petroleum Hydrocarbons (TPH) contamination. An additional investigation of the site has been completed by CGL in March 2012, and consisted of 21 window samples, 4 deep cable percussive boreholes and a series of dynamic probe tests. Monitoring wells were also installed on site to allow for the completion of soil gas and groundwater monitoring.

The investigation was largely confirmatory of the original findings outlined within the Albury SI report, in that a significant thickness (maximum 6.0m) of variable Made Ground was encountered over the London Clay Formation, which was proven to a maximum drilled depth of 35.0mbgl. The clay was noted to be slightly weathered towards the surface and became still to very stiff around 13.0 to 18.0mbgl. In two of the deepest boreholes (BH3 and BH4), the clay became very sandy with depth and groundwater was encountered in

sandy partings at depths in the order of 22.0m to 24.0mbgl. Perched groundwater also identified in the Made Ground at depths in the order of 3.2m to 5.7mbgl.

Chemical analysis of the soils has indicated that generally contamination is present at acceptable concentrations in relation to assessment criteria for a '*Commercial'* end land use. Notwithstanding this, the majority of Made Ground will be removed to approximately towpath level to accommodate a lower ground floor level area. Traces of hydrocarbons (staining and odours) were noted within soils removed from locations drilled near to the USTs on site. Whilst the concentrations are considered acceptable, this may be indicative of leaks/spills and so the reduced level formation should be inspected once again post tank removal. The tank decommissioning/removal process should be supervised by a Geoenvironmental Engineer.

Generally the total soils and Waste Acceptance Criteria (WAC) testing has confirmed that the majority of soils may be disposed as *non hazardous* waste. Two of the WAC tests have indicated that there may also be discrete areas of material that can be disposed as *inert* waste. However, two hotspots have also been identified; asbestos was positively identified in WS1 in a cemented form, but not elsewhere in exploratory holes across the site. Dependent upon the volume identified, it may mean that some of the soils in the total area local to WS1 could be classified as *hazardous* waste. Also in WS4, material was classified as hazardous waste on the basis of elevated lead concentrations. The test data can be used to form a waste disposal strategy that can be agreed with the receiving landfills to see that the correct classification is applied and waste volumes are minimised. The excavation/waste disposal process should be supervised by a Geoenvironmental Engineer.

Whilst the vast majority of Made Ground soils will be removed from site, some material may remain. Therefore, a capping layer comprising of 300mm fresh topsoil/subsoil is recommended to promote healthy plant growth in soft landscaped areas. Additionally, all potable water supply pipework should be Protectaline, or a similar specification.

Given the anticipated loads of the development, the recommended foundations for the proposed structure are bored piles formed into the London Clay. The retaining walls for the lower ground level should be contiguous pile walls, with an appropriate internal drainage cavity between the pile wall and internal facing, discharging to a positive sump, to accommodate residual groundwater seepages through the wall.

Suspended floors will be required to accommodate any movement due to heave. The final pile design should also allow for heave protection as the London Clay has high to very high volume change potential. Elevated sulphate has been recorded on site, which indicates that buried concrete within Made Ground and the London Clay Formation should be designed to Design Sulfate Class DS-5 and ACEC Class AC-5. However, in accordance with BRE Special Digest 1, a Design Chemical (DC) Class for cast-in-situ concrete of DC-3 is deemed to be appropriate based on the available information, assuming an intended working life of at least 100 years and section thicknesses greater than 450mm with some chemical attack being acceptable.

1. INTRODUCTION

Urbanest UK Limited has commissioned Card Geotechnics Limited (CGL) to undertake an intrusive ground investigation to assess geotechnical conditions and potential environmental risks associated with the redevelopment of the site of 103, Camley Street, London, NW1 0PF. The site's location is shown on Figure 1.

These works have been undertaken in relation to proposed redevelopment of the site to include substantial multi-storey student accommodation, with a lower ground floor level and 'incubation' space intended for student business enterprises.

CGL previously completed a *Stage 1 Geoenvironmental report*[1] for the site, which should be read in conjunction with this document.

This report presents a summary of earlier reports that have been completed for the site by CGL and Albury SI, the findings of the present intrusive investigation and includes a risk assessment with an updated conceptual site model to determine any ground-related environmental issues associated with the site. The investigation also includes geotechnical information and recommendations for foundation and floor slab design.

This report includes the following:

- Review of salient information from previous reports;
- Details of site works undertaken and the ground conditions encountered;
- Logs and factual data to generate geotechnical design parameters and assist foundation and sub-structure design;
- Chemical laboratory test data and characterisation;
- Geotechnical and geoenvironmental recommendations for the proposed development;
- Contamination risk assessment and remediation and waste disposal classification;
- Development of an updated Conceptual Site Model (CSM).

[1] CGL. (2011). Stage 1 Geoenvironmental report: 103 Camley Street, London. CG/5521. Rev 1

2. DESK STUDY AND SITE VISIT

2.1 Site location and description

The site is located off Camley Street in the London Borough of Camden to the north, northwest of Saint Pancras International Station. The Ordnance Survey Grid Reference for the site location is 529720, 183780.

The site location is presented in Figure 1.

2.2 Proposed development

The anticipated development will comprise multi-storey student accommodation of up to 12 storeys, with incubation space for student business enterprise, cycle parking and a café in a lower ground level formed by the reduction of site levels from that adjacent to Camley Street to that of the Regent's Canal towpath. Areas of green space will be incorporated adjacent to the canal towpath. Anticipated lower ground and ground floor layouts are provided as Figures 2a and 2b respectively.

2.3 Site walkover

A site walkover was completed as part of the earlier *Stage 1 Geoenvironmental report* that was completed by CGL. It was noted that two warehouses are present in the east of the site and are occupied by a dry food goods warehouse and toy business. In addition to the warehouses, several informal containers are noted on site as well as portacabins used as a café, and there are open areas that are used for taxi parking. Evidence for Underground Storage Tanks (USTs) was noted on site. London Fire Brigade Planning Authority confirmed the likely presence of five tanks that held petrol, diesel and gas oil. The tank that contained petrol was filled with water in 1989; the status of the remaining tanks is unknown.

The site is positioned adjacent to the towpath that runs parallel to the Regent's Canal, however, the site is some 5m above the level of the canal. An electrical substation is noted off site towards the southeast.

2.4 Historical development

The *Stage 1 report* indicated that the site once formed part of the Midland Railway infrastructure, with a large Goods Depot building extending over the eastern part of the site that was later demolished. After this time, two rectangular shaped structures were developed to the eastern perimeter of the site and are still present on site today.

2.5 Previous reports

Several reports have been completed for the site, which are summarised in the *Stage 1 report*; salient details from some these documents are summarised as follows:

Albury SI completed a ground investigation in 2000[2], which indicated the presence of some 5 to 6m of Made Ground on the site, comprising notable concentrations of heavy metals, particularly lead and Total Petroleum Hydrocarbons (TPH) and Polycyclic Aromatic Hydrocarbons (PAH). The hydrocarbons appeared to coincide with the area of the buried tanks.

CGL completed a *Stage 1 Geoenvironmental report* for the site in November 2010 (Revised August 2011), which comprised a search of the past land usage of the site and of potential contaminative land uses. It also included a preliminary assessment of the ground and groundwater conditions and the provision of a preliminary conceptual site model (CSM) for the site. The CSM indicated that there was a generally medium risk potential for contamination, but high in the area of the underground fuel storage tanks.

CGL also completed an *Outline remediation method statement*[3], based on the desk study information, to set out the measures that will be required to protect the users of the development, the general public and the environment during the construction and operation stages. It also sets out the basis of the validation procedures that will be in place to confirm compliance with the remediation methodology.

2.6 Anticipated ground conditions

According to the British Geological Map Sheet 256[4] the site is shown to be underlain by the London Clay Formation. The previous investigation completed by Albury SI indicated that there was a significant thickness of Made Ground overlying the natural strata. In the upper horizons, the Made Ground was noted to consist of brick rubble and earth predominantly. With depth, it comprised mainly a silty clay with brick fragments.

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[2] Albury SI. (2002). 103 Camley Street: Letter report. Reference: 00/4901/NVM/CM/rpt. 12th December 2000.
[3] CGL. (2010). Outline Remediation Method Statement: 103 Camley Street. CG/5521. November, 2012.
[4] British Geological Survey (1994). North London, England and Wales Sheet 256. Drift Geology. 1:50,000.

2.7 Radon

Reference to the BRE[5] and HPA[6] guidance documents on radon protection measures indicates that the site is not positioned within a radon affected area, and that less than 1% of homes are below the action level. Therefore, no special precautions are considered necessary for new developments at this site.

2.8 Hydrogeology and hydrology

The Environment Agency[7] has produced an aquifer designation system consistent with the requirements of the Water Framework Directive. The designations have been set for superficial and bedrock geology and are based on the importance of aquifers for potable water supply, and their role in supporting surface water bodies and wetland ecosystems.

The London Clay Formation is designated as 'Unproductive Stratum', which contains insignificant quantities of groundwater. The site does not lie within a Source Protection Zone and there are no potable water abstraction points near to the site.

The site is positioned some 5m above, but adjacent to, the Regent's Canal. Information obtained as part of the *Stage 1 report* indicated the canal is likely to have been constructed within the natural underlying strata, i.e. the London Clay Formation

On this basis, the risk to controlled waters is considered to be minimal.

2.9 Preliminary conceptual site model

An earlier CSM was included within CGL's *Stage 1 report*. This was based on the available information and past land uses identified in and around the site and the anticipated ground conditions.

Generally a medium risk potential for contamination was identified, but this was anticipated to be higher in the area of the USTs. This risk was assigned on the basis that a significant thickness of Made Ground was identified on site during the Albury SI investigation and that the on site USTs may have leaked.

[5] BRE. (1999). Radon: Guidance on protective measures for new buildings. Building Research Establishment, Report BR211, 1999
[6] HPA. (2007). Interactive atlas of radon in England and Wales. Health Protection Agency, HPA-RPD-033, 2007
[7] www.environment-agency.gov.uk (2012)

3. PRESENT GROUND INVESTIGATION

3.1 General

An intrusive investigation was completed by CGL from the 2nd to the 19th April 2012 and comprised of four cable percussive boreholes (BH1-4) with associated in-situ testing and sampling. 21 window sample holes were completed using a tracked rig to obtain samples for contamination analyses. A series of dynamic probes were completed at two locations that extended inwards towards the site from the retaining wall. These positions were completed to determine the extent of the heel to the wall.

All of the exploratory hole locations were agreed in advance of site works with the Client and were completed in zones on the basis that the site is fully operational and becomes heavily trafficked by vehicle. The holes were positioned to allow for a suitable coverage of the site but were also targeted in relation to specific sources of contamination, such as the tanks and the substation. The indicative exploratory hole locations are shown on Figure 3.

Prior to the completion of site works, a full service search was completed on site by a specialist contractor. The survey drawing showing the services and all of the exploratory hole locations is in Appendix A. This also included a survey by means of Ground Penetrating Radar (GPR), which was used to located the buried tanks. Five tanks were located, which was consistent with information that was provided by LFB Planning Authority in the *Stage 1 report*. An output image showing the USTs is provided as Figure 4. In addition to the tanks, a tunnel was also identified which extended from the centre of the site in a south west direction. The full extent of the tunnel could not be determined and it is unclear as to its original purposes. However, there is the potential that this was part of the former Midland Railway infrastructure.

Potential hazards were discussed with the drilling crew and machine operators prior to the commencement of works and the CGL Engineer used a Cable Avoidance Tool (CAT) at each location as a precautionary measure to check for the presence of electrical services.

The boreholes were drilled by means of a Dando shell and auger rig to a maximum depth of 35.0m bgl. Standard Penetration Tests (SPTs) were carried out at regular intervals and were alternated with undisturbed sampling. The exploratory holes were positioned to enable suitable site coverage and upon completion were installed with gas and groundwater monitoring well equipment. Two of the deeper boreholes (BH3 and BH4) were dual installed with a shallow standpipe extending through the Made Ground and a deeper standpipe that extended towards the base of the drilled hole.

Upon completion of the window samples locations, the arisings were backfilled in reverse order and reinstated at the surface with concrete. Three window samples were re-drilled in order that they could be backfilled with concrete to allow a noise/vibration impact assessment to be completed. These positions are marked as V1-V3 on the survey drawing. This assessment is being completed by others and is no longer referred to in this document.

The investigation was undertaken in general accordance with the requirements of BS 5930:1999[8] and BS 10175:2011[9]. The exploratory holes were logged and representatively sampled by the CGL Engineer.

The full stratigraphic logs are provided in Appendix B and geological cross sections are provided in Appendix C.

3.2 Monitoring

Following the completion of the investigation, the installed monitoring wells were left to equilibrate for approximately one week. Subsequently, six gas and groundwater level monitoring rounds were completed on a weekly basis. The monitoring results are in Appendix G.

On the first monitoring round there was an issue with one of the monitoring wells (BH3), in that blockages were identified within both of the standpipes. The drilling crew attended site on the second monitoring visit to repair the wells.

3.3 Laboratory testing

3.3.1 Geotechnical

Selected geotechnical samples were classified and analysed by Geolabs Limited for the following parameters:

- Particle Size Distribution (PSDs);

[8] BSI (1999). Code of Practice for Site Investigations BS 5930:1999. British Standards Institution.
[9] BSI (2011). Investigation of Potentially Contaminated Sites – Code of Practice. BS 10175:2011. British Standards Institution, 2011.

- Moisture content and Atterberg Limits;
- Quick undrained triaxial testing;
- Water soluble sulfate and pH determination;
- Consolidation/swelling tests by odeometer.

The results are in Appendix D.

3.3.2 *Chemical*

Selected soil samples were dispatched to i2 Analytical Limited, a UKAS and MCERTS accredited laboratory, for the following analyses:

- Soil Organic Matter (SOM);
- pH determination;
- Metals, including arsenic, barium, beryllium, boron cadmium, chromium, copper, lead, mercury, nickel, selenium, vanadium and zinc;
- Total cyanide;
- Acid soluble sulfate;
- Total monohydric phenols;
- Speciated Polycyclic Aromatic Hydrocarbons (PAH) and;
- Speciated Total Petroleum Hydrocarbons (TPH).

Selected samples were also tested for Polychlorinated Biphenyls (PCBs) and asbestos identification on the basis of site observations.

Leachate testing was completed on eight samples for a similar suite of determinands as those outlined above; twelve samples were submitted for Waste Acceptance Criteria (WAC) testing. All of the chemical results are in Appendix F.

4. GROUND AND GROUNDWATER CONDITIONS

4.1 General

The ground conditions encountered during the intrusive investigation are summarised in Table 1 below but were largely confirmatory of the anticipated ground conditions. Generally, the site is underlain by a significant thickness of Made Ground of variable composition over the London Clay Formation. Partings of sand were noted at depth with the London Clay in the deeper boreholes where groundwater was also encountered. These sandy horizons suggest that the lower beds of the London Clay Formation are present in this area.

4.2 Soils

Table 1: Ground conditions summary

Strata	**Depth to top of stratum (m bgl)**	**Thickness (m)**
Reinforced concrete and/or brick paviours. [MADE GROUND/HARDSTANDING]	0.0	0.1-0.5
Consisting of varying horizons of sandy gravel, gravelly sand and/or gravelly clay. Gravels are of flint, brick, concrete, glass, clinker, coal, metal, wood and ceramics. [MADE GROUND] *(*Smaller thicknesses of Made Ground are recorded due to refusal being met on brick/concrete obstructions)*	0.10-0.50	* Up to 6.00
Firm orange grey brown mottled silty sandy CLAY (weathered London Clay) becoming stiff to very stiff dark grey sandy CLAY with depth. In BH3 and BH4 siltstone was noted at depths of 22.65m and 19.80m respectively. Sand partings were also noted in these boreholes at depths of 24.1m and 21.35m respectively. [LONDON CLAY FORMATION]	4.20-6.20	Proven to 35mbgl

Further details of the ground conditions encountered are detailed in the following sections. The full stratigraphic logs are provided in Appendix B and geological cross sections are provided in Appendix C. A plot of SPT ‘N’ values vs. depth is provided as Figure 5 and a plot of Cu values against depth is provided as Figure 6.

4.2.1 Made Ground

The Made Ground was encountered across the site below the concrete/brick paviour hardstanding. The composition was variable, with horizons of sandy gravel and/or gravelly sand over gravelly silty clay. The Made Ground had a limited biodegradable fraction within the matrix. Very organic material was only noted in WS1, WS2A and WS16 comprising rotting timber/wood and organic peaty clay.

Generally the Made Ground comprised gravels of flint, brick, concrete, ceramic, metal and clinker. A number of concrete/brick obstructions were encountered during window sampling, which meant that some of the positions were either relocated or terminated at shallow depths. The obstructions appeared to be more prevalent along the west of the site where the retaining wall is located.

This is consistent with the borehole drilling crew's observations whereby brick rubble and concrete boulders were noted in the starter pits that were hand dug for BH2 and BH4. SPT tests taken within the Made Ground returned 'N' values in the range of 10 to 24 in the granular fill, which corresponds to material that is medium dense and 9 to 11 in the clay fill, which corresponds to material that is soft to firm (where $f_1 = 5$).

Some of the SPTs did not extend through the full length of the test and so the data was extrapolated to give SPT-N values in the range of 80 to 187. These values are inconsistent with the other values recorded in the fill, therefore, it is likely that the SPT could not penetrate through the material due to the presence of brick and concrete hardcore obstructions.

Visual and olfactory evidence of contamination was noted in several of the window sample holes in the Made Ground. In WS1 a cemented fibrous fragment of material was noted at 0.8mbgl. This was segregated and submitted for asbestos identification; the results are discussed in Section 5.0. In addition, black staining and/or a hydrocarbon odour was noted in locations WS1, 6, 7, 9-13A, 18 and 19. Generally, these observations were made in the locations that were positioned closest to the USTs, which is consistent with previous findings made by Albury SI. Whilst this may be indicative of the tanks having leaked historically, there was no gross contamination ie: free product noted. Therefore, the extent of leakage is considered to be somewhat limited.

4.2.2 London Clay Formation

The London Clay Formation was encountered in some of the window samples and all of the boreholes below the Made Ground. In some cases, the clay was noted to be weathered at shallow depths, consisting of firm orange grey brown mottled silty sandy London Clay nearer to the top of the stratum. Generally, the formation was encountered as stiff to very stiff dark brown sandy clay.

SPT-N values recorded in the clay were in the range of 11 to 49. Generally, the material had correlated *(f_1 = 4.5)* Cu values between 50kPa to 220kPa (SPT-N to Cu), which generally increased with depth and indicated the material to be 'firm to very stiff'.

The results of six triaxial tests on undisturbed samples between 6.0mbgl and 19.5mbgl returned undrained shear strengths in the range of approximately 51kPa and 149kPa, which correspond with the correlated Cu values determined from the SPT results and generally increase with depth. The results of the geotechnical classification analyses have indicated index properties for the London Clay in the following ranges:

- Moisture Contents between 23% and 36%;
- Liquid Limits between 56% and 79%;
- Plastic Limits between 23% and 34%; and
- Plasticity Indices between 32% and 46%.

On this basis the London Clay may be classified as a clay of high to very high plasticity[10] with a medium to high volume change potential[11]; a plasticity chart is presented as Figure 7.

Consolidation tests were completed at depths of 6.0m and 8.0m in the London Clay to determine the likely heave effect on the clay following the removal of the Made Ground. It has been estimated that some 5.0m of Made Ground may be removed from the site, which would equivalent to removing approximately 100kPa overburden on the clay. Basic heave calculations have been completed using the unloading stages of the consolidation. It is estimated that there may be some 50 to 90mm of heave following the removal of the Made Ground in the unconstrained case, although actual figures will be influenced by the moderating effects of pile and retaining wall installation.

All of the geotechnical results are provided in Appendix D.

4.3 Dynamic probing

Dynamic probe tests (DPTs) were completed at two locations against the retaining wall. The purpose of these works was to ascertain the extent of the heel of the wall that flanks the south west of the site. A plan showing the test locations is provided as Figure 8.

The tests were completed at regular intervals at locations that extended from the wall inwards towards the site. Eight DPTs were completed at location DP1 and three DPTs were completed at location DP2. Generally the probes that were formed closest to the wall met refusal at depths between 1.2m and 1.4mbgl at both DP1 and DP2. Refusal was met from the wall to approximately 2.5-3.5m inwards of the site. Beyond this, the probes advanced straight through to depths of 8.0mbgl, where the test was terminated.

It is unlikely that the heel of the wall has been encountered because it would not be situated at depths where refusal has been recorded. When comparing the results to the logs, it is noted that there were several window samples holes that refused along this flank of the site. In addition, the drilling crew recorded rubble and concrete boulders. Therefore, it is possible that a zone of hardcore material has been placed behind the wall historically when the site levels were being increased with fill material. This material is preventing the probes from advancing through the Made Ground, therefore, it is recommended that trial pits are excavated once the site has been cleared to determine the extent of the heel of the wall.

The dynamic probe results are provided in Appendix E.

4.4 Sulfate and pH

Water soluble sulfate results have been returned in the range of 410 to 6600mg/l and pH has been recorded in the range of 7.2 to 10.3 in samples taken from the Made Ground. The sulfate content within the London Clay at depth was in the order of 1300 to 8000mg/l and pH was in the range of 7.2 to 8.1.

[10] British Standards Institution. (1999). Code of practice for site investigations. BS5930:1999 Inc. Amendment 2.
[11] National House-Building Council. (2007). Building Near Trees- Chapter 4.2.

On the basis of testing completed in the London Clay, 40% of the samples tested have a percentage of oxidisable sulfate greater than 0.3%. Therefore, it is possible that there may be pyrite present in the London Clay. This is discussed further in Section 6.7.

The results of all chemical tests are included in Appendix F.

4.5 Groundwater

During window sampling, perched water was noted in the Made Ground in WS1 at 5.20mbgl, WS6 at 3.60mbgl and BH1 at 5.7mbgl. Water seepage was also noted in WS14 at 3.2mbgl. In the boreholes, groundwater was generally not encountered. However, in the deepest boreholes (BH3 and BH4), groundwater was encountered within the sandy partings noted at depth. Therefore, these boreholes were installed with a deep standpipe (as well as a shallower standpipe with a response zone through the Made Ground), in order that the groundwater could be monitored.

Six monitoring rounds have been completed subsequent to the intrusive investigation; the groundwater levels are summarised in Table 2 below:

Table 2: Groundwater level summary

Exploratory hole	Groundwater (mbgl)					
	26.04.12	02.05.12	10.05.12	17.05.12	24.05.12	31.05.12
BH1	5.09	4.98	5.11	5.14	5.16	5.16
BH2	4.24	3.28*	3.28	3.38	3.53	3.52
BH3 (Shallow)	NR	4.82	4.74	4.91	4.92	4.92
BH3 (Deep)	NR	9.82	6.83	6.32	6.42	6.40
BH4 (Shallow)	4.28	4.32	4.52	4.55	4.60	4.68
BH4 (Deep)	5.90	5.43	5.62	5.59	5.67	5.70

Notes:

NR Not recorded due to problem with monitoring well

* Standing water from the surface went into the standpipe when the bung was removed

Sandy partings were noted towards the base of BH3 and BH4, where a groundwater strikes were recorded at depths of 24.05m and 22.40mbgl respectively. During monitoring, these levels were noted to rise to depths in the range of 5.43m to 9.82mbgl, which are likely to be reflective of the long term water table in the London Clay. Water that has been encountered within the shallower installations and during drilling of the window samples is likely to be representative of perched water within the Made Ground above the more impermeable London Clay below.

4.6 Soil gas

Gas monitoring was completed from the 26th April to the 31st May 2012 by a CGL Engineer when atmospheric pressure was recorded between 990 and 1023mb. Monitoring was completed during periods at which atmospheric pressure was below 1000mb and when it was rising and falling.

Positive and negative flow rates were detected on site, with the maximum flow being recorded in BH2 at 1.8l/hr. Oxygen was recorded in the range of 19.0 to 21.0%. Methane was not detected on site. Carbon dioxide was recorded in the range of 0.0 to 0.5% by volume in air. A Photo Ionisation Detector (PID) was used to detect the presence of Volatile Organic Compounds (VOCs). The readings were negligible and were all 0.0 parts per million.

The monitoring records are provided in Appendix G.

5. CONTAMINATION ASSESSMENT

5.1 Human health assessment

Representative samples from the present investigation were selected for laboratory analysis. The test results have been compared against the published Soil Guideline Values (SGVs) for the "commercial" land-use category to assess the risk to human health from chemical contamination. Whilst the site is being redeveloped for student residence, the majority of the Made Ground will be removed to allow for a lower ground level to be constructed. At this level, it is proposed that 'incubation spaces' will be provided for student business enterprises. In addition, there will be no areas for private gardens and so the 'commercial' land use category is considered appropriate for the site in question.

Currently, SGVs have only been issued by the Environment Agency for a limited number of contaminants, namely selenium, mercury, arsenic, nickel, the BTEX compounds, phenol and cadmium. The SGVs have all been issued for a sandy loam soil with a Soil Organic Matter of 6% as standard.

Where SGVs are not available, the soil results have been compared to Generic Assessment Criteria (GACs) that have been derived in-house by CGL using the *Contaminated Land Exposure Assessment (CLEA)* model[12] and version 1.06 of the CLEA software. The GACs represent conservative screening criteria and have been calculated using the default parameters for the standard land use scenario set out in the CLEA technical report and toxicological inputs in line with the requirements of *Science Report SC050021/SR2*[13] and, in the case of petroleum hydrocarbons, Science *Report P5-080/TR3*[14]. The GACs have been generated assuming a sandy loam soil type and a Soil Organic Matter of 1%, which are suitable assumptions for the site in question. More detailed information on the derivation of the CGL GACs can be provided upon request.

Assessment against the SGVs and GACs is carried out at the 95th percentile on the sample mean (designated US_{95}), which is considered to represent a reasonable worst-case scenario. The US_{95} has been rounded up to the nearest whole number. Statistical

[12] Environment Agency. (January 2009). *Updated technical background to the CLEA model*. Science Report SC050021/SR3.
[13] Environment Agency. (January 2009). *Human health toxicological assessment of contaminants in soil*. Science Report SC050021/SR2.
[14] Environment Agency. (February 2005). *The UK Approach for Evaluating Human Health Risks from Petroleum Hydrocarbons in Soils*. Science Report P5-080/TR3.

assessment of the results has been completed in accordance with the recommendations set out in the recently published CL:AIRE guidance[15]. In this regard, an assessment of the normality of the data has been undertaken. Where datasets are normally distributed the one sample t-test has been applied to calculate the US_{95}. In the case of non-parametric datasets, the Chebychev Theorem has been applied. The Grubbs Test has also been used to identify potential outliers within datasets. Copies of the relevant statistical analysis are available on request.

The results of the assessment are set out below in Tables 3a and 3b. A copy of the factual data is included as Appendix F.

Table 3a: Summary of soil contamination (risks to human health)

Contaminant	SGV or GAC @ 1% SOM for Commercial land-use (mg/kg)	Notes on soil saturation limits (SSL)[1]	Measured range (mg/kg)	US_{95} (mg/kg)	US_{95} > Assessment Criteria? (Y/N) #- outlier detected
SOM (%)	*[2]		0.6-5.7	*	*
Arsenic	640[3]	-	3.2-29	17.13	N#
Cadmium	230[3]	-	<0.2-1.6	0.39	N
Chromium (total)	330	-	6.7-78	39.44	N
Chromium (III)	9,600	-	37-78	59.95	N
Chromium (VI)	35	-	<4	<4	N
Lead	6,800	-	21-2500	664.89	N
Mercury (inorganic)	3,600[3]	-	<0.3-2.6	1.00	N
Selenium	13,000[3]	-	<1.0	<1.0	N
Boron	*		<0.2-6.5	2.48	*
Copper	73,000	-	23-230	104.30	N
Nickel	1,800[3]	-	7-57	33.61	N
Zinc	330,000	-	35-1900	356.16	N#
Barium	*		37-1300	285.84	*
Beryllium	220	-	0.2-3.8	1.46	N#
Vanadium	5,500	-	8.5-90	62.54	N
Phenols[4]	750[3]	(c)	<2	<2.0	N
Cyanide	*		<1-2	1.12	*
BTEX compounds					
Benzene	29[5]	-	<0.001-0.18	0.02	N#

[15] J. Lowe et al. (May 2008). *Guidance on comparing soil contamination data with a critical concentration*. CL:AIRE, CIEH & SAGTA.

Contaminant	SGV or GAC @ 1% SOM for Commercial land-use (mg/kg)	Notes on soil saturation limits (SSL)[1]	Measured range (mg/kg)	US_{95} (mg/kg)	US_{95} > Assessment Criteria? (Y/N) #- outlier detected
Toluene	870[5]	(d)	<0.001	<0.001	N
Ethyl benzene	520[5]	(d)	<0.001	<0.001	N
m-xylene[6]	630[5]	(d)	<0.001	<0.001	N
o-xylene[6]	480[5]	(d)	<0.001	<0.001	N

Notes:
1. - = green; (a) = amber i.e. GAC set to model output, [SSL provided in square brackets] ; (b) = red i.e. SSL exceeded & considered to affect interpretation. GAC calculated in accordance with the CLEA Software Handbook ; (c) = based on direct contact; (d) GAC limited to SSL.
2. * = no value currently defined
3. Based on published Soil Guideline Value (Environment Agency, 2009), adjusted for 1% SOM
4. GAC relates to Phenol (C_6H_5OH) only and is based on direct skin contact
5. Based on the published SGVs for BTEX at 6% SOM (Environment Agency, 2009), adjusted for 1% SOM
6. Concentrations for total xylenes should be compared to the value for m-xylene for fresh spills and to o-xylene for all other cases.

Table 3b: Summary of soil contamination (risks to human health) cont.

Contaminant	SGV or GAC @ 1% SOM for Commercial land-use (mg/kg)	Notes on soil saturation limits (SSL)[1]	Measured range (mg/kg)	US_{95} (mg/kg)	US95 > Assessment Criteria? (Y/N) #- outlier detected
Total Petroleum Hydrocarbons (TPH)					
TPH aliphatic EC5-6	370	(d)	<0.1	<0.1	N
TPH aliphatic EC>6-8	170	(d)	<0.1	<0.1	N
TPH aliphatic EC>8-10	93,000	(b)	<0.1	<0.1	N
TPH aliphatic EC>10-12	95,000	(b)	<1.0	<1.0	N
TPH aliphatic EC>12-16	95,000	(b)	<2-67	12.34	N
TPH aliphatic EC>16-35	1,900,000	(b)	16-360	86.06	N
TPH aromatic EC5-7	29	-	<0.1-0.2	0.11	N
TPH aromatic EC>7-8	870	(d)	<0.1	<0.1	N
TPH aromatic EC>8-10	34,000	(b)	<0.1	<0.1	N
TPH aromatic EC>10-12	38,000	(b)	<1	<1	N
TPH aromatic EC>12-16	38,000	(b)	<2-20	4.97	N
TPH aromatic EC>16-21	26,000 [60]	(a)	<10-140	32.56	N
TPH aromatic EC>21-35	28,000 [4.8]	(a)	<10-290	49.07	N
Polycyclic Aromatic Hydrocarbons (PAH)					
Acenaphthene	110,000	(b)	<0.1-2.10	0.02	N
Anthracene	530,000 [7.7]	(a)	<0.1-5.9	0.99	N
Benzo(a)anthracene	192 [1.7]	(a)	<0.2-14	2.39	N

Contaminant	SGV or GAC @ 1% SOM for Commercial land-use (mg/kg)	Notes on soil saturation limits (SSL)[1]	Measured range (mg/kg)	US_{95} (mg/kg)	US95 > Assessment Criteria? (Y/N) #- outlier detected
Benzo(a)pyrene	22 [0.9]	(a)	<0.1-13	0.48	N#
Benzo(b)fluoranthene	220 [1.2]	(a)	<0.2-5.8	0.99	N#
Benzo(g,h,i)perylene	2,200 [0.02]	(a)	<0.05-8.0	1.35	N#
Benzo(k)fluoranthene	220 [0.7]	(a)	<0.2-5.8	1.14	N#
Chrysene	2,100 [0.4]	(a)	<0.05-14	2.47	N#
Dibenzo(a,h)anthracene	22 [0.004]	(a)	<0.2-1.2	0.32	N#
Fluoranthene	72,000 [19]	(a)	<0.2-33	5.60	N
Fluorene	64,000 [150]	(a)	<0.2-2.3	0.51	N#
Indeno(1,2,3-cd)pyrene	210 [0.06]	(a)	<0.2-6.9	1.24	N#
Naphthalene	23,000	(b)	<0.05	<0.05	N
Pyrene	54,000 [2.2]	(a)	<0.2-27	4.57	N#

Notes:

1. - = green; (a) = amber i.e. GAC set to model output, [SSL provided in square brackets] ; (b) = red i.e. SSL exceeded & considered to affect interpretation. GAC calculated in accordance with the CLEA Software Handbook ; (c) = based on direct contact; (d) GAC limited to SSL.

The results of the statistical analysis indicate that there are no unacceptable concentrations of contamination across the site in comparison to the assessment criteria for the chosen land use scenario. Traces of TPH and benzene were noted in some locations that were advanced near to the underground fuel storage tanks. Whilst the concentrations were below the associated assessment criteria, this may be indicative of historic leaks/spills from the tanks. Therefore, the soils below the tanks should be inspected further following their removal. This is discussed further in Section 7.4.

Selected samples were submitted for PCB analysis given the presence of an electrical substation off site. The results that were returned were all below the limits of detection, therefore, the risk from this source is considered to be minimal. In addition, a sample of fibrous material was taken from one of the window sample locations and was submitted for asbestos identification. The laboratory has positively identified chrysotile fibres within the sample. Whilst other evidence of Asbestos Containing Materials (ACMs) was not noted during the investigation, it is possible that asbestos might be present in other areas across the site. This is discussed in Section 7.3

5.2 Risks to controlled waters

Given the nature of the local hydrological and hydrogeological regime, the risk to controlled waters is anticipated to be minimal. The site is underlain by the London Clay Formation, which is designated as an 'Unproductive Stratum' by the EA. Therefore, no groundwater samples have been taken as part of these works. However, eight soil samples were submitted for leachate analysis in order to assess the risks from mobile contamination; the results are reported in Table 4. The results have been compared to Environmental Quality Standards (EQS) and the Drinking Water Values (DWV). When given the local ground conditions, this is considered to be a stringent assessment for the site in question.

Table 4: Summary of leachate results

Contaminant	Freshwater EQS[1] (µg/l)	EC Drinking Water Value (µg/l)	Measured range (µg/l)	No. of samples exceeding EQS	No. of samples exceeding Drinking Water Value
Arsenic	50	10	2.2-8.7	0	0
Cadmium	5	5	<0.1	0	0
Chromium	250	50	1.5-9	0	0
Lead	**250**	**10**	**1.4-21**	**0**	**2 of 8**
Mercury	1	1	<0.5-0.9	0	0
Selenium	*[2]	10	<4.0	*	0
Boron	2000	1000	29-170	0	0
Copper	28	2000	2.6-12	0	0
Nickel	200	20	1.2-4.4	0	0
Zinc	500	(5000)[3]	2.3-14	0	0
Barium	*	(1000)[3]	12-81	*	0
Beryllium	(15)[4]	*	<0.2	0	*
Vanadium	60	*	<1.7-13	0	*
Phenols	30	(0.5)[3]	<10	0	LOD > DWV
Cyanide	5[5]	50	<10	LOD > EQS	0
Sulfate (mg/l)	400	250	7.6-190	0	0
TPH	*	(10)[3]	<10	*	0[8]
PAH	*	0.1[7]	<0.04	*	0[8]
Benzo(a)pyrene	*	0.01	<0.01	*	0
Naphthalene	10	*	<0.01	0	*
Benzene	30	1	<1.0	0	0
Toluene	50	*	<1.0	0	*
Ethylbenzene	*	*	<1.0	*	*
Xylenes	30	*	<1.0	0	*
MTBE	*	*	<1.0	*	*
pH	6.0 - 9.0	6.5 - 10.0	6.5-7.9	0	0

The results of the groundwater sample analysis have indicated that, where tested, chemical determinands are generally present at acceptable concentrations below the EQS and DWV values. However, lead is present at concentrations that exceed the DWV in two of the samples tested. Lead was detected at a maximum concentration of 21µg/l, which exceeds the DWV of 10µg/l but not the EQS. However, as the hydrogeological and hydrological setting of the site is not greatly sensitive, the risk from this contaminant to controlled waters is considered to be minimal.

In the case of cyanide and phenols, the laboratory limits of detection exceed the EQS and DWV respectively in the groundwater sample. However, the total soil concentrations of phenols and cyanide are below the limits of detection and so it is unlikely that there would be any significant phenol or cyanide contamination within the dissolved phase. The factual data is provided in Appendix F.

5.3 Updated qualitative risk assessment

A preliminary Conceptual Site Model was provided in the initial *Stage 1 Geoenvironmental report*, which identified the potential pollutant linkages that may have existed at the site in accordance with Contaminated Land Report (CLR) 11[16]. The risks identified are in accordance with the DEFRA and Contaminated Land Report (CLR) 6[17], site prioritisation and categorisation rating system which is summarised in Table 5 below.

[16] The Environment Agency (2004) Model Procedures for the Management of Land Contamination, CLR 11
[17] M.J. Carter Associates (1995) Prioritisation and Categorisation Procedure for Sites which may be Contaminated, Department of the Environment, CLR 6

Table 5: Risk Rating Terminology

Risk Rating	Description
High Risk	Contaminants very likely to represent an unacceptable risk to identified targets Site probably not suitable for proposed use Enforcement action possible, Urgent action required
Medium Risk	Contaminants likely to represent an unacceptable risk to identified targets Site probably not suitable for proposed use Action required in the medium term
Low Risk	Contaminants may be present but unlikely to create unacceptable risk to identified targets Site probably suitable for proposed use Action unlikely to be needed whilst site remains in current use
Negligible Risk	If contamination sources are present they are considered to be minor in nature and extent Site suitable for proposed use No further action required

Based on the above terminology, an assessment of the risks posed by the potential pollutant linkages at the site is outlined in the Updated CSM, which has been reviewed on the basis of findings from the present ground investigation and is presented as Table 6.

Table 6: Qualitative Risk Assessment

Source/Medium	Receptor	Potential Exposure Route	Risk Rating
Explosive / asphyxiating gases from within Made Ground (if present)	Internal building spaces & future occupiers	Migration of gases through the surface and via permeable soils	Low to negligible risk as no methane, and minimal concentrations of carbon dioxide have been identified.
Asbestos within Made Ground (if present)	Construction workers	Direct ingestion of soil & dust, inhalation of particulates & vapours and dermal contact	Medium risk as evidence of asbestos has been identified in one location, however, this is in a cemented form, limited in extent and risks can be mitigated.
Organic/inorganic contaminants (e.g. PAHs, TPH, metals etc.) within Made Ground (if present) and potential fuel spillage	Construction workers	Direct ingestion of soil & dust, inhalation of particulates & vapours and dermal contact	Low risk as minimal concentrations of contaminants have been identified, however, there is potential that hydrocarbon contamination may be present below the buried tanks.
	Future site occupiers	Direct ingestion of soil & dust, inhalation of particulates & vapours, indirect ingestion by means of dermal contact	Low to negligible risk given that the majority of Made Ground will be removed and/or encapsulated beneath structures thus minimising leaching.
	Controlled waters	Migration via leaching/transport in groundwater	
	Vegetation and plants	Root uptake	Low risk as planting is likely to be minimal as it will be landscaped, therefore, vegetables are unlikely to be grown on site.
	Buildings & structures	Direct contact and migration & accumulation within building spaces	Low risk given that no VOCs have been recorded on site, and the sources of contamination will be removed. Elevated sulphate has been identified on site.
PCBs from the former railway industry and the electrical substation.	Construction workers	Direct ingestion of soil & dust, inhalation of particulates & vapours and dermal contact	Low to negligible risk given that the potential sources are predominantly located off site. PCBs are not present at concentrations above the limits of detection.
	Future site occupiers	Direct ingestion of soil & dust, inhalation of particulates & vapours and dermal contact	

Despite there being a significant thickness of Made Ground across the site, the gas regime has been identified as being very low risk. Minimal concentrations of carbon dioxide (0.5%) and methane (0.0%) have been recorded, which may be because a minimal biodegradable fraction was encountered within the soil matrix. Asbestos was identified in one location, which could mean that further fragments of cement bound fragments or loose fibres are present within the soil, although given the history of the site, the occurrences would be isolated and restricted to the upper layers if present. Therefore, site workers should employ the use of Personal Protective Equipment (PPE) to mitigate the risk from contact with fibres, particularly inhalation, as a sensible precaution. The presence of asbestos may also have implications for waste disposal, which is discussed in Section 7.3.

Limited soils contamination has been encountered on site; traces of hydrocarbons were noted in window sample locations that were drilled close to the underground fuel storage tanks. Whilst these contaminants have been identified at acceptable concentrations, there is the potential that more significant contamination may be present closer to/below the tanks. The tanks should be decommissioned and removed as part of the future development so that the soils in this area can be inspected and removed if they have been grossly impacted. This is discussed further in Section 7.4. The risk from hydrocarbon vapours is considered to be low given that negligible VOC concentrations has been detected during monitoring and because the tanks will be removed from site.

Elevated sulfate has been identified in both the Made Ground and natural soils. This may have implications for buried concrete structures, however, this risk can be mitigated by using an appropriate design class of concrete, which is discussed in Section 6.7.

The risk to plants is considered to be minimal as the development proposals include landscaped/border vegetation as opposed to private gardens where homegrown vegetables might be grown.

A diagrammatic CSM is provided as Figure 9.

6. GEOTECHNICAL RECOMMENDATIONS

6.1 General

The anticipated development will comprise multi-storey student accommodation of up to 12 storeys, with 'incubation space' for student business enterprise, cycle parking and a café in the ground floor level. Areas of green space will be incorporated adjacent to the canal towpath.

The following recommendations are based on the ground and groundwater conditions encountered during the present ground investigation and the results of subsequent testing for geotechnical parameters.

6.2 Geotechnical Design Parameters

Geotechnical design parameters for the proposed development are summarised in Table 7 below. These are based on the results of SPT testing, geotechnical laboratory testing, and published data for the well-studied London geology.

Table 7: Geotechnical design parameters

Stratum	Design Level (mOD)	Bulk Unit Weight γ_b (kN/m^3)	Undrained Cohesion c_u (kPa) [c']	Friction Angle ϕ' (°)	Young's Modulus E_u (MPa) [E']
Made Ground (Granular)	28	19	-	28[b]	[14]
Weathered London Clay	22.5	20	50 + 10z[c] [5]	24[a]	30 + 6z[d] [22.5 + 4.5z][e]
London Clay	15	20	130 + 3.2z[c] [5]	24[a]	78 + 1.9z[d] [58.5 + 1.5z][e]

a. BS 8002:1994 Code of practice for Earth retaining structures, British Standards institution.
b. Peck, R.B., Hanson, W.E., and Thornburn, T.H., Foundation Engineering, 2nd Edn, John Wiley, New York, 1967, p.310.
c. z = depth below surface of the London Clay
d. Based on 600Cu
e. Based on 0.75Eu

The parameters in Table 14 are unfactored 'moderately conservative' design values.

6.3 Excavations

Based on the ground conditions encountered excavations required during the development should not pose significant difficulties for conventional excavators and earthmoving equipment. However, it should be noted that concrete obstructions may be present near to the retaining wall.

As the dynamic probing, completed as part of the present investigation, did not delineate the extent of the heel of the retaining wall on site it is recommended that a machine excavator is used during the demolition or groundworks phase of the development to determine the extent of this feature. Given the variable nature of the Made Ground, it is necessary that any trial pits excavated against the wall are suitably shored and supported.

Excavation of the lower ground level will take place to approximately 5.0 to 6.0mbgl through the Made Ground. Perched groundwater has been identified in the Made Ground at levels in the order of 3.28m to 5.14mbgl. Therefore, groundwater control may be required during the basement excavation (see Section 6.5).

Excavations in excess of 1.2mbgl should be suitably shored or otherwise supported or battered and should be inspected regularly by a competent person. No operatives should enter unshored or otherwise unprotected excavations.

6.4 Foundations

Based on the anticipated development loads and the recorded ground conditions, pile foundations are considered appropriate for the site. At this stage specific column loads have not been provided.

Given the ground conditions and urban nature of the site it is likely that continuous flight auger (CFA) will be appropriate to limit disturbance to neighbours. The use of CFA piling methods will also overcome the potential for pile bore collapse due to water ingress in the sandier zones of the London Clay. Preliminary pile working loads are presented in Figure 10 based on CFA piles with an adhesion value of 0.5 within the London Clay and a factor of safety of 2.6 as recommended in current LDSA guidance[18]. This assumes that no pile testing is undertaken. It should be noted that this factor of safety can be reduced to 2.2 on completion of a representative number (1% of total number of piles) of working load tests and to 2.0 on completion of working load tests and preliminary pile tests.

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[18] LDSA. (2009*). Foundations, No.1 Guidance Notes for the Design of Straight Shafted Bored Piles in London Clay*.

Indicative pile safe working loads are summarised in Table 8 below based on 25m effective length piles with a toe level at circa -3mOD and a cut-off level of circa 22mOD (i.e. 2m below lower ground floor level).

Table 8. Summary of preliminary pile safe working loads (FoS = 2.6).

Pile Diameter (mm)	Safe Working Load (MN)
600	1.48
750	1.90
900	2.35

Depending on column loads either single piles or pile groups may be utilised. Final pile design should be undertaken by the piling contractor.

6.5 Retaining walls

Retaining walls for the lower ground floor will be required in those areas away from the towpath. It is anticipated that the basement will be constructed using contiguous or secant bored pile walls, dependent on groundwater conditions and basement drainage requirements. Based on the groundwater conditions encountered on-site (see Section 4.5), groundwater is largely limited to small volumes of perched water in the Made Ground. As such a contiguous pile wall with an appropriate internal drainage cavity between the pile wall and internal facing is recommended to accommodate residual groundwater seepages through the wall in the permanent condition.

It is recommended the basement retaining walls toe a minimum of 1m into the London Clay to provide an effective groundwater seal during construction. It is likely a greater depth will be required to ensure stability if the retaining wall is to be designed as a cantilever. Given that only a limited number of adjacent structures are generally in close proximity, and given the history of ground level raising in the area are likely to be supported by piled foundations, the risk of damage to neighbouring structures is considered to be low and a cantilevered solution is feasible. The retaining wall will be supported in the permanent condition by the lower ground floor and ground floor slabs.

The basement box should be dewatered, if required, to below formation level so that the lower ground floor slab can be cast. Groundwater control could take the form of a sump drainage system with active collection pumps. It is envisaged an effective seal into the London Clay will limit potential recharge following dewatering so that pumping will only be required to remove residual seepage. Once dewatered, minimal groundwater seepage through, or beneath the pile walls is anticipated and it is likely this could be controlled by localised sump pumping. A design groundwater level of 23.5mOD should be adopted for temporary works.

Geotechnical parameters for retaining wall design are provided in Table 7. For short term temporary works undrained parameters for the London Clay should be adopted, however should the pile wall remain in the cantilevered condition for periods of greater than 3 months, drained parameters should be used.

6.6 Lower ground level and slab

The London Clay will be subjected to some stress relief as some 5.0m of Made Ground is removed. Due to the cohesive nature of the London Clay (silty clays), they are likely to be affected by seasonal shrink-swell and subject to some volume change during unloading and loading. Basic heave calculations have been completed and it is estimated that there may be some 50 to 90mm of heave following the removal of the Made Ground. Therefore, the design should also allow for heave protection as the London Clay has high to very high volume change potential.

As such it is considered a suspended lower ground floor slab is adopted for the development, incorporating an appropriate compressible material or void former beneath the slab to accommodate heave movements.

Similarly a void, void former or compressible material should be provided against the inside faces of external pile caps. Piles should be reinforced to a depth sufficient to counteract heave forces causing uplift over the upper portion of the pile shaft.

6.7 Pavement design

A CBR value of 2% is recommended for roads and pavements founded where Made Ground is to be retained. The material should be proof rolled, and if pockets of weak material are encountered these should be removed and replaced with well compacted granular fill.

6.8 Drainage

Infiltration testing was outside of the scope of works for the present investigation. However, on the basis of the ground conditions encountered, soakaways would not be recommended as a suitable drainage option for the site due to the anticipated infiltration rates.

Other suitable Sustainable Drainage System (SuDS) options may be available for the site, which should be discussed with a specialist drainage consultant. Any such system would need to have a high degree of storage to attenuate against low infiltration rates.

6.9 Buried concrete

Based on BRE Special Digest 1[19], buried concrete within Made Ground and the London Clay Formation should be designed to Design Sulfate Class DS-5 and ACEC Class AC-5 assuming mobile groundwater.

This is a high design grade of concrete even within the London Clay Formation, which comprises sulfate-bearing selenite. Also on the basis of the testing completed, there is potential that there may be pyrite present in the London Clay. This can be problematic in situations where the ground is disturbed to the extent that the pyrite is exposed to oxidising conditions giving rise to sulfate ions, which may affect the concrete.

However, on the basis that piled foundations have been recommended for the site, in the London Clay, it is likely that ground disturbance in the formation will be minimal. This risk will also be mitigated by the use of the higher design chemical class for concrete.

In accordance with BRE Special Digest 1, a Design Chemical (DC) Class for cast-in-situ concrete of DC-3 is deemed to be appropriate based on the available information, assuming an intended working life of at least 100 years and section thicknesses greater than 450mm with some chemical attack being acceptable.

At shallower depths where Made Ground will remain, it may be possible to replace the Made Ground with non-sulfate bearing material such as Type 1 fill in order that the design grade for buried concrete can be reduced at such depths. However, it may not be practical to make this differentiation during development construction, in which case the higher classification would need to apply to buried concrete.

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[19] BRE Construction Division. *Concrete in aggressive ground*. Special Digest 1:2005. 3rd Edition.

7. CONTAMINATION RECOMMENDATIONS

7.1 General

The following recommendations have been made on the basis that the future development will involve the removal of the majority of Made Ground and will consist of a commercial space at the lower ground level. With reference to potential contamination issues, the '*Commercial*' end land use is considered to be most appropriate for the site.

The following recommendations are based on the ground and groundwater conditions encountered during the present ground investigation and the results of subsequent testing for contamination parameters.

7.2 Soil contamination and remediation

Gross contamination was not identified across the site in terms of a '*Commercial'* end use scenario. Where tested, all of the determinands were present at acceptable concentrations in relation to available SGVs and CGL GACs. Nevertheless, site workers should follow health and safety procedures, outlined in Section 7.10, as standard when working in close contact with exposed soils.

Beneath the building footprint the floorslab will act as a physical barrier to isolate any residual soil contamination and prevent vertical infiltration of surface water. No remediation measures are expected in this part of the development.

Where areas of Made Ground are left in-situ and/or soils will be exposed, a capping layer is recommended as discussed in Section 7.2.1

7.2.1 Capping layer

The capping layer should consist of a thickness of 300mm of topsoil and subsoil. It is anticipated that this thickness of cover will be appropriate to act as a barrier to above ground receptors and promote healthy plant growth in the areas of soft landscaping.

The imported soil should be clean, 'non waste' soil imported from a known and reputable source. A greenfield source should be utilised where possible. Chemical test results and details of source will be provided by the Contractor prior to the material being brought to site. The material will not exceed the Maximum Permissible Concentrations set out in

Appendix H. In addition, the topsoil will meet the requirements of BS 3882:2007 Classification – General Purpose Grade or better, and should be free from propagules of aggressive weeds.

Once on site, the imported material will be subject to validation testing. At least one chemical test will be undertaken for every $50m^3$ of imported material. Imported earthworks material, including general fill, should be subjected to a similar testing regime if any is required.

7.3 Material management and waste classification

It is anticipated that the majority of soils requiring disposal will be generated during the removal of the Made Ground from site. A Geoenvironmental Engineer should be present at this time in order that material of a similar composition can be stockpiled and sampled to allow for waste characterisation.

In general, the total soil analysis and subsequent WAC testing has indicated that the Made Ground can be disposed at a *non hazardous* landfill facility. WAC test results for material in WS 6 at 0.6m and WS7 at 3.0m may be disposed at an *inert* facility if required. There may be other discrete areas of material that could be classified as *inert*, which is likely to apply to areas of brick and concrete rubble that have been identified. Such material should be stockpiled so that samples for further WAC analysis can be completed. A sampling frequency of 1 per $250m^3$ for small waste streams and 1 per $500m^3$ for larger volumes could be applied.

Screening of the arisings may permit recycling/reuse of the material for other sites under the WRAP protocol[20] or the CL:AIRE protocol[21] and would lead to a reduction in disposal requirements. Therefore, it is recommended that the excavation of the Made Ground is completed in zones in order that any potentially grossly contaminated material (identified by discolouration, odour etc.) can be segregated from potentially re-useable material, such as concrete and other hardcore materials. It is recommended that the tank removal is completed first in order that cross contamination can be minimised.

In WS4 at 0.5mbgl, the material has been classified as hazardous on the basis of the lead concentration. It will be necessary to segregate this material to allow for separate disposal at a *hazardous* landfill. Again, further areas of hazardous material may be present on site

[20] WRAP. (n.d.) *The Quality Protocol.*
[21] CL:AIRE.(2011). *The Definition of Waste: Development Industry Code of Practice.* Version 2.

particularly where the underground fuel tanks are located. Therefore, these areas particularly should be inspected by a Geoenvironmental Engineer in order that any grossly contaminated material can be segregated and sampled to determine a suitable end point for disposal.

Within the Made Ground at WS1 at 0.8mbgl, a small fragment of ACM was encountered in the form of cement type material comprising chrysotile fibres. Given the form and type of asbestos encountered and the isolated occurrence, this is considered to be a low risk to human health. With regard to waste disposal requirements, waste with >0.1% asbestos is considered *hazardous*, however, given the limited quantity encountered this is not considered to be a concern. Appropriate precautions will be however be required during construction works should further ACMs be found. This could include wetting the sides/bases of excavations, covering excavated spoil to reduce risk of fibre release (considered to be low as in the form of cemented material) and appropriate personal and respirator protective equipment (PPE/RPE).

Natural arisings which are not contaminated can be disposed at an *inert* landfill based on being classified a natural soil and a listed inert waste with no requirement for WAC testing.

All material intended for off site disposal should be transported and disposed in accordance with the Environmental Protection (Duty of Care) Regulations, 1991 and the Landfill (England and Wales) Regulations, 2002 (as amended). Waste legislation stipulates that *hazardous* and *not hazardous* waste should be pre-treated prior to disposal. Pre-treatment can be undertaken either at the site of origin or may be carried out at a licensed off-site facility and can include selective segregation of soils conducted on site.

7.4 Removal of tanks and decommissioning

The present investigation involved a GPR survey of the site, which confirmed the location and number of tanks in the vicinity of the retaining wall on the western boundary. In total, five buried tanks were identified, which is consistent with information presented in the *Stage 1 Geoenvironmental report.*

It is recommended that the tanks are decommissioned in accordance with PPG2[22] and the Health and Safety Executive guide CS 15: *Cleaning and gas freeing of tanks containing flammable residues*. Suitable fire fighting equipment and emergency spill response materials should be retained on site during this phase.

All decommissioning and removal works should be supervised by a competent foreman at all times and all leaks and spills monitored and controlled to prevent spread of contamination. Any liquid in the tanks should be pumped out, including liquid requiring a hand pump to remove. The contents of the tanks should be transferred to a tanker for off site disposal or recycling at a licensed facility. Any solids or sludge should also be removed. All tanks should be removed from the ground by lifting with suitable plant.

After the removal of the tanks and associated pipework etc., it would be prudent to inspect the area below the tanks to determine whether the underlying soils have been impacted. Hydrocarbon impacted arisings will have to be stockpiled to enable testing for waste classification as per the recommendations in Section 7.3.

In addition, the tanks, contents and fittings should be transferred to a registered waste carrier for off site disposal at a licensed landfill or recycled as scrap metal. Transport of the tanks should be in accordance with all applicable regulations, including the Environmental Protection (Duty of Care) Regulations. Waste disposal documentation should be retained for validation purposes.

7.5 Groundwater

Leachate testing has indicated that lead is potentially mobile at concentrations that exceed the Drinking Water Value. However, because the site is not positioned within a groundwater protection zone and is underlain by the London Clay Formation this assessment criterion is considered stringent for the site. Given the ground conditions on site, it is not anticipated that there is a viable pathway for mobile contamination to migrate to potable water sources and so the risk to groundwater is considered to be low to negligible.

Perched groundwater has been identified within the Made Ground and so there is the potential that this water will be encountered during the main ground excavation and may require dewatering. As there is potential for this water to have been impacted by contamination, it should be extracted, stored, transported or treated and disposed of in accordance with current legislation to a foul sewer under a short term trade effluent consent agreed with the water authorities.

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[22] EA. (2010). PPG2 Above ground oil storage tanks. Environment Agency.

7.6 Surface water

The site is located adjacent to the Regent's Canal, therefore, measures will be required to see that spills/run-off from the site cannot enter the water body. This will largely be achieved by removing the USTs from site and by controlling the migration of perched groundwater by dewatering.

In this regard, it is recommended that inspection of the canal side is completed daily to check for evidence of contamination migration as part of a watching brief, which is discussed in Section 7.7.

7.7 Watching brief and discovery strategy

It is recommended that a Geoenvironmental Engineer is present on site through the majority of the ground works phase. However, during times when this is not possible, then a watching brief should be maintained by the Main Contractor. Should any gross contamination, such as oily material or material of an unusual colour or odour, be encountered during excavation, the following strategy is recommended:

1. Work to cease in that area.

2. Notify Geoenvironmental Engineer, to attend site and sample material in case it is spread around. Notify Contaminated Land Officers of the London Borough of Camden.

3. Geoenvironmental Engineer to supervise the excavation of contaminated material, which should be placed in a bunded area and covered to prevent rainwater infiltration.

4. Soil samples should be obtained by the Geoenvironmental Engineer from both the excavated material, and the soils in the sides and base of the excavation to demonstrate that the full area of contamination has been excavated. If appropriate, in-situ testing should be undertaken on the sides and base of the excavation to assess the presence of residual contamination in the soils.

5. On receipt of chemical test results, the soils may be appropriately classified for treatment or disposal, and dealt with accordingly.

6. Detailed records of the stockpile sizes, source and location should be kept and regularly updated to allow materials to be easily tracked from excavation until leaving the site.

7.8 Gas protection measures

Gas screening values have been calculated in accordance with CIRIA 665[23]. Using the maximum flow rate and based on the maximum concentration for CO_2, the Gas Screening Value (GSV) is calculated as 0.009l/hr. Therefore, the site conforms to Characteristic Situation 1 and hence no specific gas protection measures are required.

7.9 Services

Based on the lack of site specific data relating to the proposed locations of pipe runs, and in accordance with current UKWIR[12] guidance, the use of barrier pipes for water supply may be required. Water supply pipes should be non-plastic, ductile iron or proprietary hydrocarbon resistant pipes such as Protectaline, to prevent possible permeation of residual hydrocarbons into drinking water supplies. The local water supply company should be contacted for the exact specification that is required in light of the remaining concentrations of contaminants in the remaining Made Ground.

7.10 Health and safety

All site works will be undertaken in accordance with the guidelines prepared by the Health and Safety Executive (HSE, 1991)[24]. In this context, the risks will be low, and nominal safety precautions should be acceptable (the adoption of good hygiene practices and the use of overalls, gloves and dust masks if necessary).

During the redevelopment, precautions should be taken to minimise exposure of workers and the general public to potentially harmful substances. Attention should also be paid to restricting possible off-site nuisance such as dust and odour emissions. Such precautions should include, but not be limited to:

1. Personal hygiene, washing and changing procedures.
2. Personal protective equipment, including disposable overalls, gloves etc.
3. Measures to avoid surface water ponding and positive collection and disposal of all on-site run-off.

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[23] CIRIA (2007). Assessing risks posed by hazardous ground gases to buildings, CIRIA Report C665, London
[24] HSE (1991). Protection of Workers and the General Public During the Development of Contaminated Land. Guidance Note HS(G)66, Health and Safety Executive, HMSO, 1991.

4. Regular cleaning of all site roads, access roads and the public highway including dust suppressions methods (e.g. water spraying), if necessary.

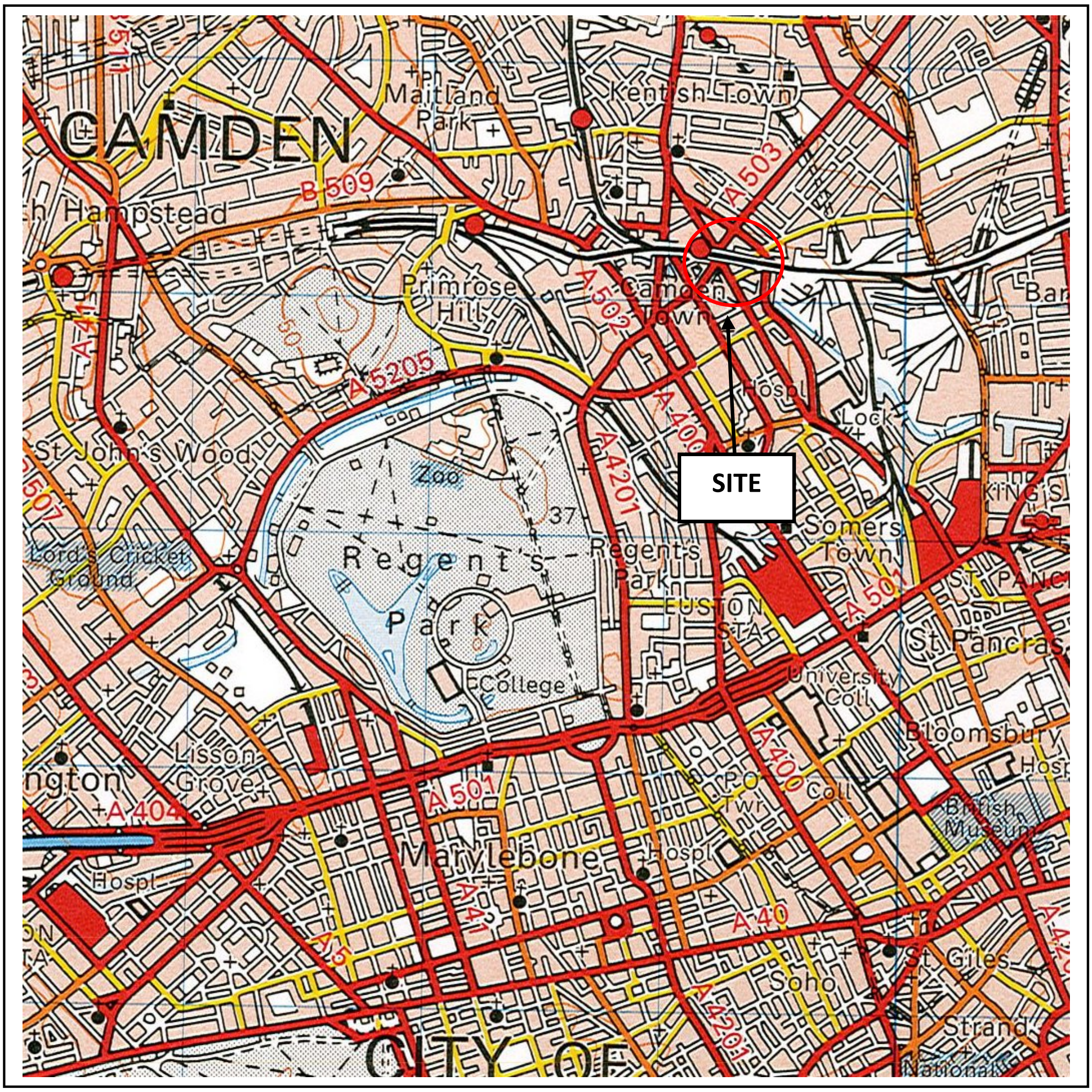
Excavations should be planned and inspected regularly by a competent person. No operatives will be permitted to enter unshored or otherwise protected excavations identified as unstable by a competent person, however shallow they are.

7.11 Regulatory requirements

This report should be submitted to the London Borough of Camden Council for their comments and approval. The contamination recommendations should be finalised in a revised *Remediation Method Statement*, which will be followed by verification works and reporting to include, but not be limited to the following:

- Site visit records and photographic records of the relevant site works.
- Location and details of all tanks and contaminated material encountered and remediation measures taken, including chemical test results for residual soils.
- Duty of care records for disposal of waste material including the landfill site(s) where the material has been disposed and a copy of the Contractor's current waste carrier's licence (to be provided by Contractor).
- Details of source and chemical test results for imported materials.
- Confirmation of capping layer thicknesses.
- Compliance testing of capping layer materials.
- Confirmation of water supply pipe materials.

FIGURES



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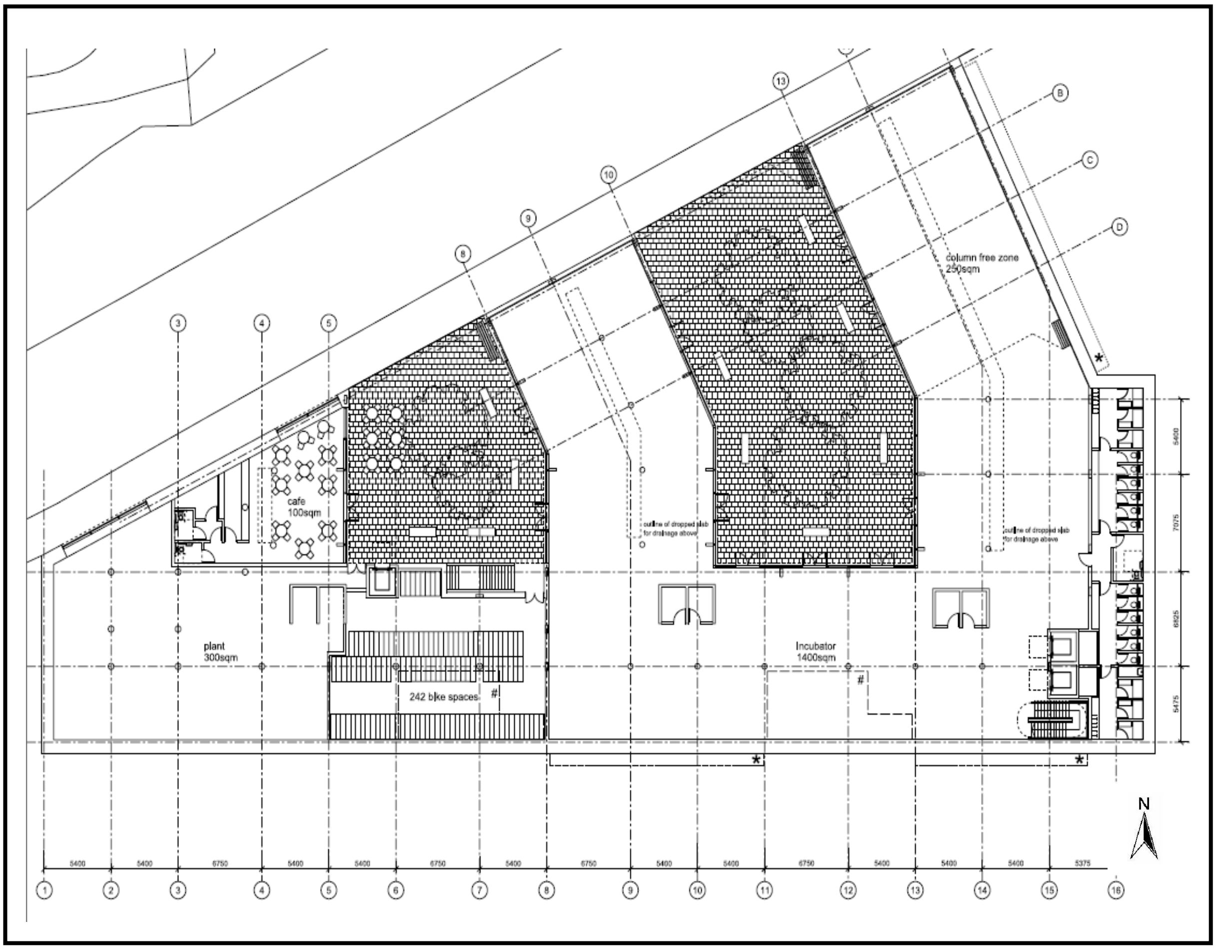
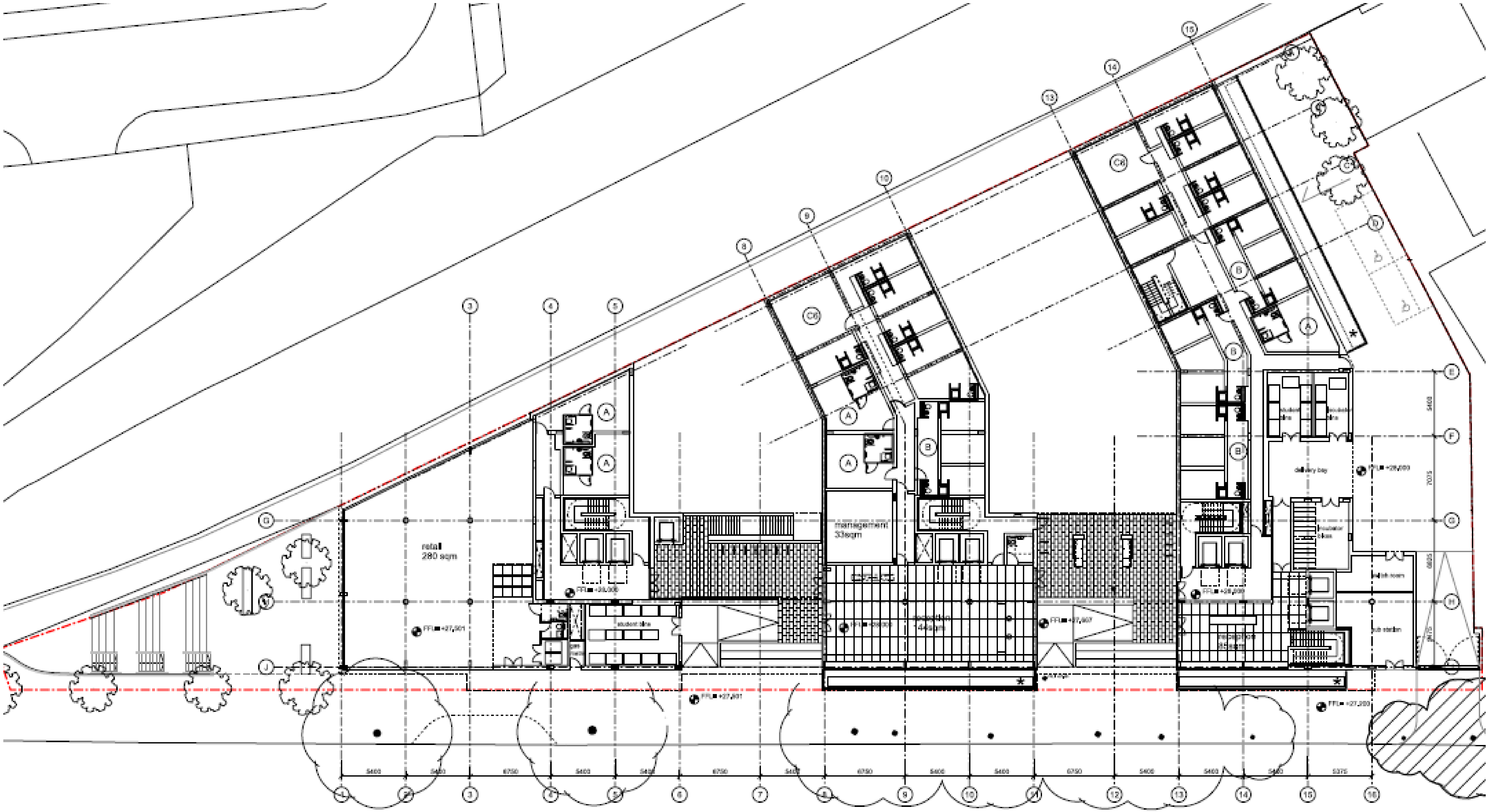
Client	Project	Job No
Urbanest UK Limited	**103 Camley Street, London**	**CG/5521c**
CGL	Title **Site location plan**	**Figure 1**



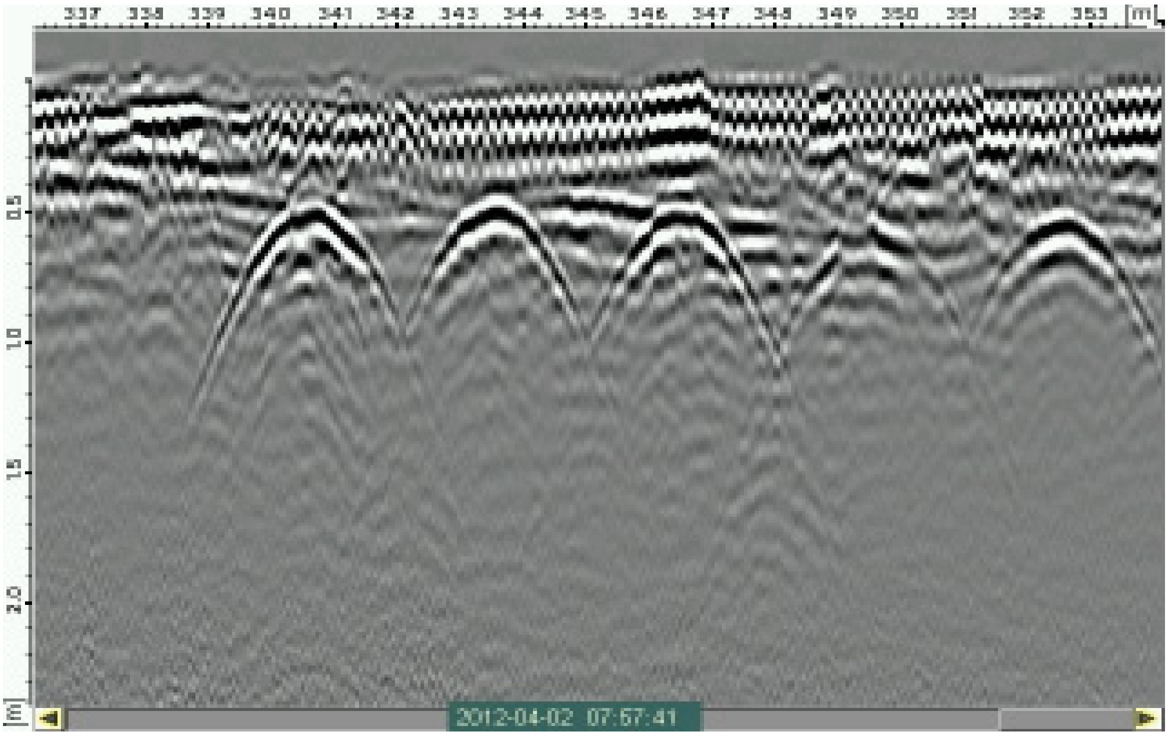
Client	Project	Job No
Urbanest UK Limited	**103 Camley Street, London**	**CG/5521c**
	Title **Lower ground floor development plan**	**Figure 2a**



Client	Project	Job No
Urbanest UK Limited	103 Camley Street, London	CG/5521c
CGL	Title Ground floor development plan	Figure 2b

Not to scale

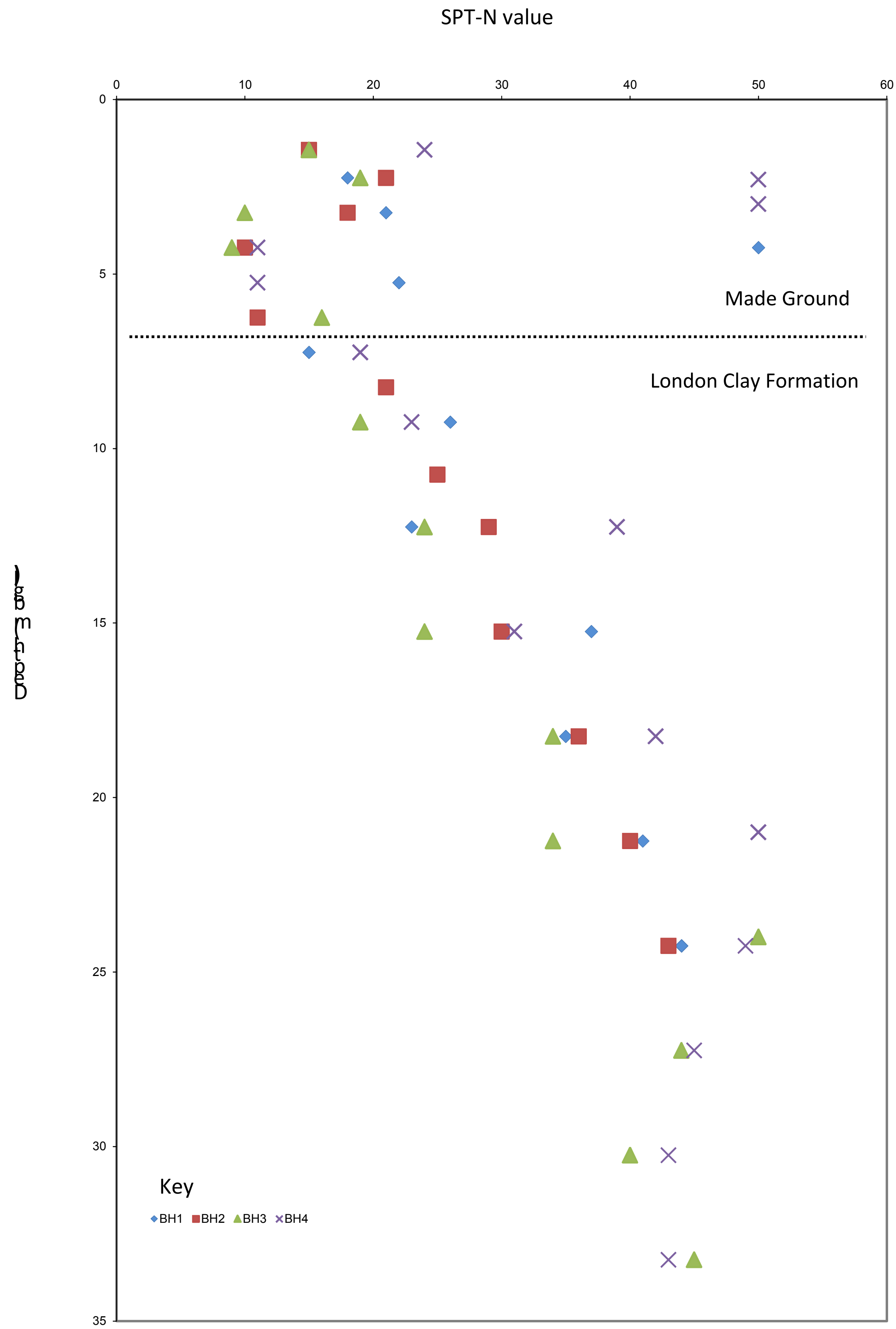
Client	Project	Job No
Urbanest UK Limited	**103 Camley Street, London**	**CG/5521c**
CGL	Title **Exploratory hole location plan**	**Figure 3**



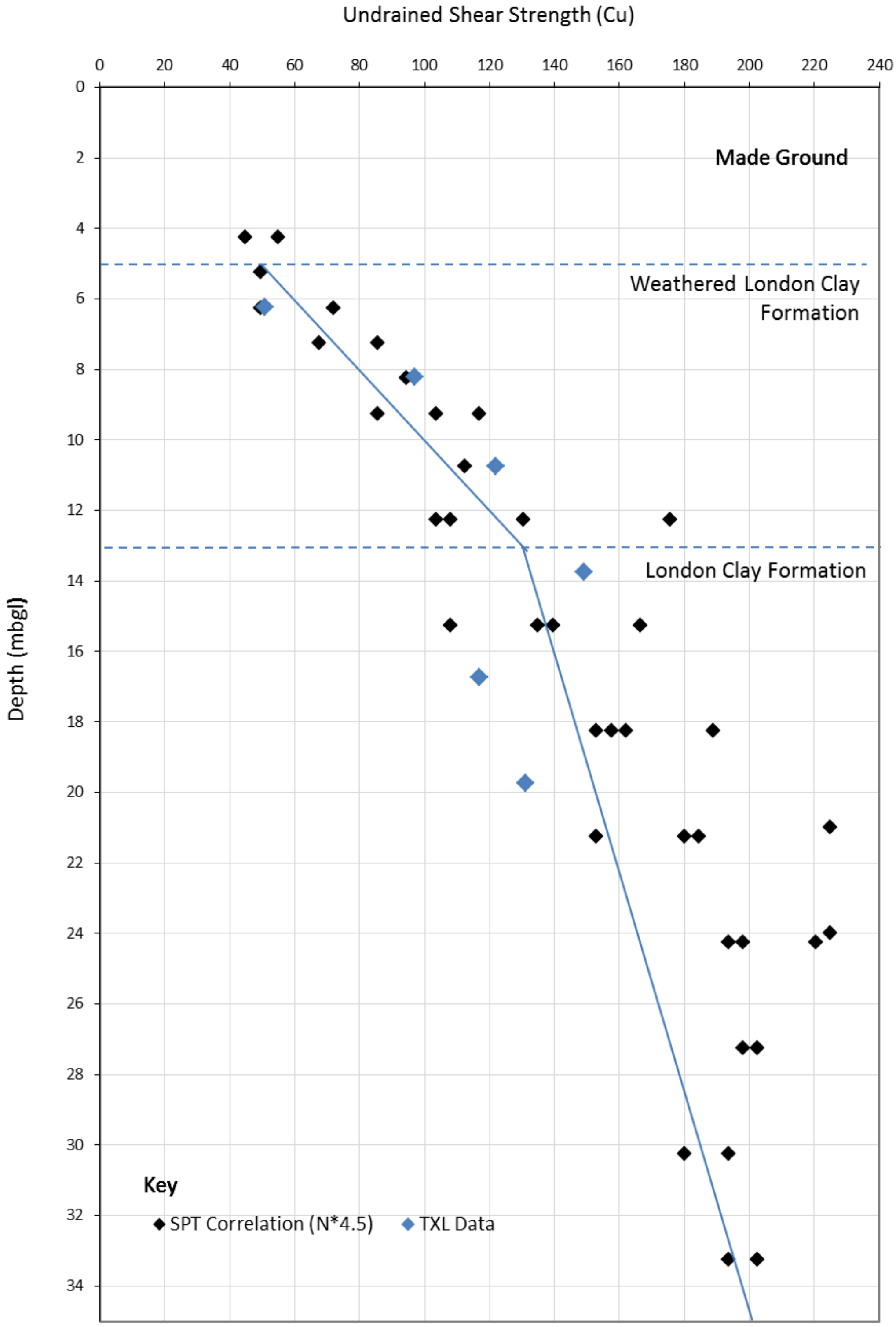
Results from Ground Penetrating Radar scan confirming the presence of five Underground Storage Tanks (USTs) in the locations shown on the final survey drawing (Reference: SL-CGL-0511/001A).

The survey is confirmatory of the information provided by LFB in the earlier *Desktop Study Report* (CG/5521), which indicated five tanks to be present on site that held petrol, diesel and gas oil.

Client	Project	Job No
Urbanest UK Limited	**103 Camley Street, London**	**CG/5521c**
CGL	Title **Underground Storage Tanks**	**Figure 4**



Client	Project	Job No
Urbanest UK Limited	**103 Camley Street, London**	**CG/5521c**
	Title	
	SPT-N vs. depth	**Figure 5**



Client	Project	Job No
Urbanest UK Limited	**103 Camley Street, London**	**CG/5521c**
CGL	Title **Undrained Shear Strength vs. Depth**	**Figure 6**